High Speed Modeling and Controls Overview

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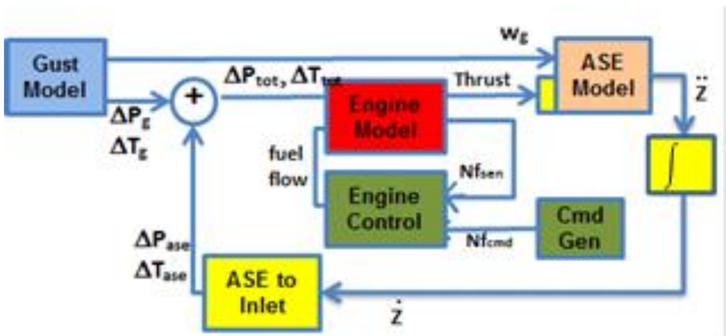
Introduction and Motivation

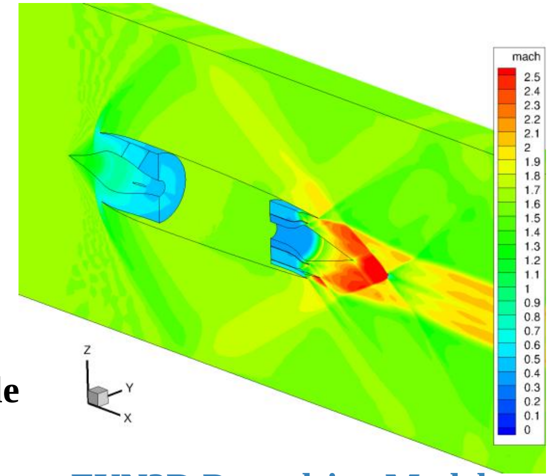
Supersonics

- NASA under the Advanced Air Vehicles Program is developing technologies and capabilities to support design of supersonic flight vehicles
  -- Technical Challenges – Noise (sonic boom, community, and propulsion)
  -- Technology areas – Several, among them AeroPropolsoServoElasticity

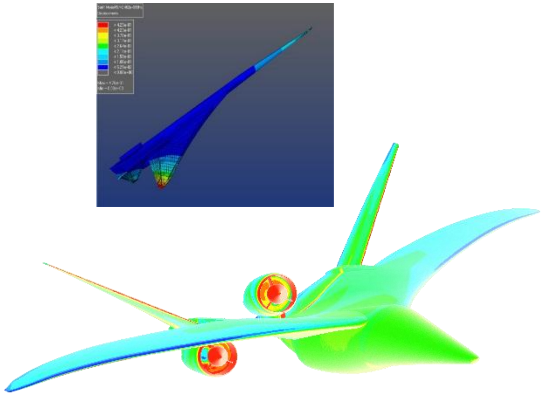
AeroPropulsoServoElasticity (APSE): The objective is to develop dynamic propulsion, structural, and aerodynamic system models and controls and integrate them together to study vehicle performance for vehicle stability, ride quality, and aerodynamic efficiency.



Integrated APSE (propulsion & structure) vehicle modeling in MATLAB/Simulink



FUN3D Propulsion Model



Integrated FUN3D Vehicle Model

Introduction and Motivation

Vehicle design needs to meet certain emissions and noise standards

TABLE 1.—LM'S PREFERRED CONCEPT WITH TECHNOLOGY INPUTS MEETS OR SURPASSES ALL N+3 GOALS

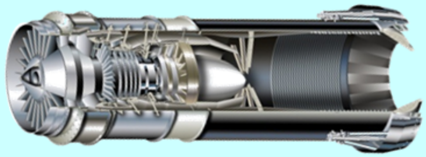
	NASA N+3 Efficient Multi-Mach Aircraft (Beyond 2030)	N+3 Goal Status
Environmental Goals		
Sonic Boom	65 to 70 PLdB low boom flight 75 to 80 PLdB unrestricted flight	70 to 76 PLdB KEY GOAL
Airport Noise	20 to 30 EPNdB (cumulative below stage 3)	18.4 (32.2 jet only) KEY GOAL
Cruise Emissions (g/kg fuel)	<5 EINOx Plus particular and water vapor mitigation	5 EINOx
Performance Goals		
Cruise Speed	Mach 1.3 to 2.0 low boom flight Mach 1.3 to 2.0 unrestricted	Mach 1.6
Range	4000 to 5500 nmi	4850 nmi
Payload	100 to 200 pax	100 pax
Fuel Efficiency	3.5 to 4.5 (pax-nmi/lb-fuel)	3.64 (pax-nmi/lb-fuel) KEY GOAL

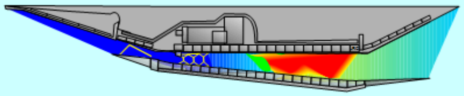
Technical Challenges (TCs)	
TC Title	**TC Description**
TC 1.1 Low Sonic Boom Design Tools	Tools and technologies enabling the design of supersonic aircraft that reduce sonic boom noise to 80 PLdB validated as ready for application in a flight demonstrator
TC 1.2 Sonic Boom Community Response Metric & Methodology	Validated field study methodology, survey tools and test protocols to support community studies with a demonstrator aircraft
TC 2.2 Low Noise Propulsion for Low Boom Aircraft	Design tools and innovative concepts for integrated supersonic propulsion systems with noise levels of 10 EPNdB less than FAR 36 stage 4 *(ICAO chapter 4)* demonstrated in ground test

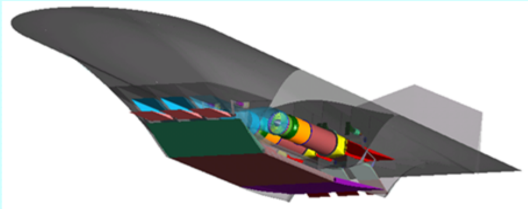
Geometry		
Length	Span	Height
244 ft	84 ft	30.5 ft
Cruise Operating Condition		
Altitude	Mach	Angle of Attack
50,000 ft	1.7	2.25 deg.

TBCC Propulsion Technologies for space access vehicles

Turbine Based propulsion + *Hypersonic Scramjet propulsion* } *Hypersonic TBCC propulsion*







High Mach Turbine Tech Challenges:

- Increase Maximum Mach from 2+ → 4+
- Provide thrust margin over entire range (0<M<4+)

Scramjet Tech Challenges:

- Reduce Scramjet Ignition Mach Speed (M5 → M3)
- Provide transition speed margin (3<M<4)

TBCC Propulsion Technology Challenges

✓ addressed by NASA CCE

- ✓ Performance and Operability over flight range
- ✓ Inlet / Engine / Nozzle Integration
- • Propulsion / Airframe Integration
- ✓ Mode Transition / Stage Separation
- • Thermal Management
- • Transonic Thrust Margin

Inlet mode transition and system integration issues are major elements

Turbine-Based Combined-Cycle Propulsion System Development for Access-to-Space

- Access-to-space launch propulsion systems are rocket powered, limited launch sites, costly operations

- Mode transition (open-loop control) has been demonstrated in wind tunnel tests for isolated high-performance inlet
- Mach 3-capable turbine engine & nozzle have been successfully SLS-tested

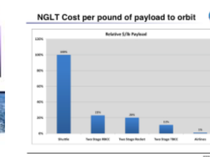
•Provide safe, reliable, reusable & economical access to space → **mature air-breathing horizontal launch propulsion system technology**

➢Stable transition from one propulsion mode to another while maintaining thrust

- Demonstrate closed-loop control strategies to enable smooth & stable mode transition for high speed flight
- System demonstration of integrated turbine engine and simulated scramjet

Horizontal Launch TBCC:

- *Lowers risk of loss of vehicle*
- *Increased operational flexibility*
- *Lowers cost per pound of payload to orbit*



- Ensure stable operation of propulsion system flowpaths during mode transition
- Develop database for CFD & controls model validation
- Integrate M3-capable turbine engine; validate operability

Table 11-1. Emission Index (grams per kilograms of fuel used) of various materials for subsonic and supersonic aircraft for cruise condition. Values in parentheses are ranges for different engines and operating conditions.

Species (gm MW)	Subsonic Aircraft* Short range	Long range	Supersonic Aircraft#
CO_2 (44)	3160	3160	3160
H_2O (18)	1230	1230	1230
CO (28)	5.9 (0.2-14)	3.3 (0.2-14)	1.5 (1.2-3.0)
HC as methane (16)	0.9 (0.12-4.6)	0.56 (0.12-4.6)	0.2 (0.02-0.5)
SO_2 (64)	1.1	1.1	1.0
NO_x as NO_2 (46)	9.3 (6-19)	14.4 (6-19)	depends on design (5-45)